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D-8000 Munich 2(DE)(54) **Downhole milling tool and cutter therefor.**

(57) A cutter for a downhole milling or cutting tool and a tool incorporating the blade has a longitudinal axis (97) about which the tool is rotatable. The tool may have a plurality of circumferentially disposed blades which are either fixed or radially movable to perform a cutting operation. Each of the cutters has a blade (100) having a cutting surface (17) which is formed by a plurality of cutting elements (20). Each of the cutting elements has a plurality of protruding cutting edges (3) each of which are longitudinally spaced from one another and interspaced from one another by a recess portion (1) so that in use swarf moves upwardly from one of the cutting edges along the recess portion and is subsequently broken off. By providing such relatively closely spaced cutting edges generally C-shaped swarf cuttings are produced and "birdnesting" is substantially reduced or eliminated. The cutting elements each have a cutting surface (41) which presents a negative radial rake angle in the range 1-10° and a lead attack angle in the range 1-15°.

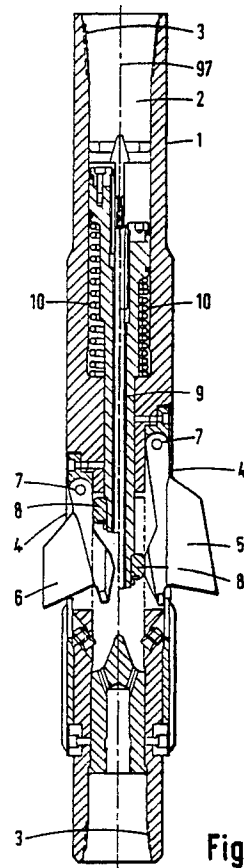


Fig.1

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DOWNHOLE MILLING TOOL AND CUTTER THEREFOR

Background of the Invention

(a) Field of the Invention

This invention relates to a downhole milling tool and to a cutter therefor for cutting tubular members downhole.

(b) Description of the Related Art

Downhole milling tools are well known and may consist of a tubular body having an axial aperture therethrough for circulation of cooling fluid and a plurality of equi-circumferentially disposed slots in the outer surface of the body. In each of the slots is located a pivotally mounted cutting blade and a means is provided for moving each of the cutting blades radially outwardly from the body. Each of the cutting blades has an outer surface facing the direction of rotation of the tool which is dressed with a cutting material. The dressing may be formed by crushed tungsten carbide chips which are randomly dispersed on the blade surface. The problem associated with crushed tungsten carbide chips is that because they have an irregular shape and size they are difficult to secure to the blade surface and such inconsistency in shape also leads to unpredictable performance in respect of swarf cutting configuration and rate of penetration. This problem has been alleviated by using tungsten carbide elements having a circular or rectangular cross-section, the tungsten carbide elements being brazed, soldered or welded to the blade. It has been found, with advantage, that if tungsten carbide elements of a regular shape are used then they may be located on the blade both radially and in an axial longitudinal direction of the blade in a regular formation such that each element provides a negative rake angle, that is, in use each blade is angled downwardly and rearwardly with respect to the vertical direction of the blade taken in the direction of rotation when in use.

The known cutting elements of regular shape have been known to be provided with a chip breaker, that is a projection which limits the length of swarf cut by the cutting edge of the element. However such known elements have only one chip breaker and once that is worn off the performance of the tool deteriorates until the next element with a new chip breaker is exposed.

It will be understood that the provision of a chip breaker is extremely desirable to overcome the phenomenon known as "birdnesting", that is long

spirals of swarf that are cut from a tubular member being machined forming into a conglomerate mass which restricts the flow of mud about a tool and reduces the rate of penetration of the tool. It is therefore an object of this invention to provide a milling tool and a cutter therefor in which the foregoing problems are substantially mitigated.

Summary of the Invention

According to one aspect of this invention there is provided a cutter for a downhole milling tool which tool is rotatable about a longitudinal axis, said cutter comprising a blade having a cutting surface, said cutting surface being formed by a plurality of cutting elements, each cutting element having a plurality of protruding cutting edges each being longitudinally axially spaced from one another and interspaced by a recessed portion, whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is subsequently broken off. Generally c-shaped swarf cuttings are thus preferably produced.

In a preferred embodiment the cutting surface extends in a generally radial direction across the intended direction of rotation of the tool and the cutting edges also extend generally radially. It is believed swarf cuttings will be assisted in moving under centrifugal force to the outer radial edge of a blade if preferably each cutting element has a negative radial rake, i.e. has a radial outer edge thereof disposed angularly rearward of a radius to the longitudinal direction with respect to a radial inner edge of said element, in the range 1-10° and preferably 5°, and the cutting edges are planar therewith.

Preferably each cutting element is located on the blade at an angle inclined to a radial direction which is perpendicular to the longitudinal axis (herein referred to as the "lead attack angle") and the elements are positioned in the longitudinal direction one above the other so that the elements provide a continuous cutting surface. Advantageously the lead attack angle is in the range 1-15° and preferably 10°.

Conveniently each cutting element is a discrete part, each of which is secured to the cutting blade by, for example, brazing or soldering or welding.

Advantageously the cutting elements of odd numbered rows extending longitudinally are in line and even numbered rows extending longitudinally are in line and the even numbered rows are offset in a radial direction by half the radial length of a cutting element from the odd numbered rows.

Advantageously each cutting element is arranged to produce a negative axial rake angle with respect to the plane of the longitudinal axis, which angle may be in the range 1-20° and preferably in the range 7-10°.

Preferably each of the cutting elements is secured over a planar leading surface of the blade and each element has a front cutting face which is inclined with respect to the rear surface thereof, said rear surface abutting the blade so that the front cutting surface is provided with said negative axial rake angle. Alternatively each cutting element has parallel front and rear faces and the leading face of the blade has a generally radial slot formed therein which is inclined in the longitudinal axial direction to present the front face of the cutting element with a negative axial rake angle. In another alternative arrangement each cutting element has parallel front and rear faces and the leading face of the blade is formed in the longitudinal direction thereof in a staircase formation with the part thereof extending in the longitudinal direction being inclined whereby when the cutting elements are positioned on the parts thereof extending in the longitudinal direction, a leading surface of the cutting element presents a negative axial rake angle. In yet another alternative each cutting element has parallel front and rear faces, the rear face being secured to a leading side of said blade and said blade being inclined with respect to the longitudinal axis to provide said negative axial rake angle.

Advantageously four cutting edges are provided on each cutting element, and preferably each of the cutting edges has a rake angle in the range 0-40°, advantageously 3-12° and a land angle in the range 0-35°, preferably 3-15°.

Conveniently the cutting elements are each quadrilateral in cross-section, conveniently square. Preferably the cutting elements extend both in a radial and a longitudinal direction over the blade leading face.

Advantageously the cutting edge protrudes from the recessed portion in the range 0.001-0.060 inches (0.025-1.5mm) preferably 0.003-0.015 inches (0.076-0.38mm).

Advantageously each cutting element is made from tungsten carbide having European ISO standard P10 to P60 hardness grade and with a cobalt content in the range 7%-20%.

Preferably each blade is located about the circumference of a tool body member and each blade is pivotally located to said body member.

According to a further aspect of this invention there is provided a rotatable milling tool for use downhole including a body having a longitudinal axis, a plurality of pivotally mounted blades circumferentially spaced around the body, slot means for receiving each blade in a contracted condition of

said blade and means for radially extending each blade, each blade having a cutting surface formed by a plurality of cutting elements, each cutting element having a plurality of protruding cutting edges each being longitudinally axially spaced from one another and interspaced by a recessed portion, whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is broken off when meeting the next, uppermost, cutting edge.

Preferably the cutting surface extends in a generally radial direction across the intended direction of rotation of the tool and the cutting edges also extend generally radially.

According to another aspect of this invention there is provided a milling tool for use in energy exploration, said tool being connectable to a drilling string and rotatable about a longitudinal axis, said tool having a cutter comprising a blade having a cutting surface, said cutting surface being formed by a plurality of cutting elements, each cutting element having a plurality of protruding cutting edges each being longitudinally axially spaced from one another and interspaced by a recessed portion, whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is broken off when meeting the next, uppermost cutting edge.

Brief Description of the Drawings

The invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 shows a partial longitudinal cross-section of a rotatable milling tool incorporating the cutter of this invention,

Figure 2 shows a side view of a cutter in accordance with this invention,

Figure 3 shows a partial side view in the direction of arrow-headed line A of Figure 2 of one embodiment of the invention,

Figure 4A shows a perspective view of a detail of the cutting element shown in Figure 3,

Figures 4B and 4C show mutually orthogonal views of the cutting element shown in Figure 4A,

Figures 5A, 5B and 5C each show further embodiments of the invention in which cutting elements are secured to a blade to provide a negative axial rake,

Figures 6A-6C show details of a cutting element of the type used in the embodiments of Figures 5B and 5C,

Figure 7 shows an enlarged partial side view of the cutting element of this invention, and

Figures 8A, 8B and 8C each show, in diagrammatic form, differing angles that may be provided

to a cutting element.

In the Figures like reference numerals denote like parts.

Description of the Preferred Embodiments

The rotatable milling tool for use downhole shown in Figure 1 has a circularly cross-section body 1 having axial passages 2 therethrough for the circulation of fluid and the upper and lower ends of the body each have an internal screw thread 3 for connecting the body to a drill string and other apparatus respectively. The body may have three to twelve, preferably six, equi-circumferentially spaced longitudinal slots 4 provided in the outer circumference thereof. Three axially long cutters 5 interspaced by three axially short cutters 6 are each mounted on a respective pivot 7 in each of the slots 4 and a respective cam 8 carried by circulating fluid operated piston 9 acts on the cutters 5, 6 so that the cutter is pivotally radially movable away from the body 1 to a cutting position (the cutter 5 only being shown radially extended). The piston 9 is biased by a compression spring 10. In operation the tool 1 is rotatable about a longitudinal axis 97.

One of the cutters 5 is shown in detail in Figures 2, 3, 4 and 5A and has a longitudinally extending blade 100, the upper end (as shown in Figure 2) being provided with a circular hole 11 through which the pivot 7 is located. The blade 100 has a necked portion 12 in which the hole 11 is situated which broadens out to a main portion 13, a radially inner side 14 along which cam 8 abrades linking to an approximately triangularly cross-sectioned rib 15. The lower part of the blade 100 has an L-shaped cutout to provide a lower, in use, edge 16.

Located over a leading surface 17 of the blade, i.e. facing forwardly in the direction of rotation of the tool, is a plurality of cutting elements 20, each as shown in Figures 4A-4C, the elements being secured to the blade by any convenient means known per se such as by brazing, welding or soldering. The cutting elements are positioned in radial rows 21, 22, 23, the lower two rows 21 each comprising four cutting elements located in abutting relationship side by side to one another, row 22 comprising three elements abutting one another side by side and row 23 comprising two elements abutting one another side by side. Each of the rows 21, 22, 23 is located in a longitudinal direction one above the other. In the embodiment of Figures 2, 3 and 4 the elements 20 are slightly spaced from one another in the longitudinal direction by a portion of blade 24. Each of the rows are staggered with respect to an adjacent row such that odd

numbered rows starting from the lower edge 16 and extending upwardly in the longitudinal direction are located to align with one another and the even numbered rows are located to align with one another, the odd numbered rows being offset from the even numbered rows by half the radial length of a cutting element, thereby forming a "brickwork" pattern. In the arrangement shown in Figure 2 the element at the radial outermost end of each row is arranged to have the lower radial outer corner in alignment with a sloping edge 25 of the blade although it is to be understood that such a requirement is not necessary for the utility of the invention. It is also to be understood that it is not necessary, although highly desirable, to arrange the cutting elements in each row in abutting radial relationship to one another.

Each cutting element has a plurality of protruding cutting edges 30, each extending radially and each being longitudinally axially spaced from an adjacent edge, each cutting edge being interspaced between one another by a recessed portion 31. In the currently preferred embodiment four cutting edges 30 are provided. Each of the cutting edges of adjacent elements 20 align with one another in a radial direction and each of the rows of cutting elements 20 are inclined to a direction which is perpendicular to the longitudinal axis, i.e. have a lead attack angle LA which is in the range 1-15° and preferably 10°.

For a better understanding of terms used herein, reference will now be made to Figures 8A, 8B and 8C where the longitudinal axis 97 of the tool is taken as a reference and the direction of rotation of the tool is shown by arrow-headed line R, and a radius of the tool, perpendicular to axis 97, is shown by line 100. In Figure 8A element 20 has a leading face 41 arranged to be inclined downwardly and rearwardly with respect to the direction of rotation R and in relation to the longitudinal axis 97 to create a negative axial rake angle RA with respect to the plane of the longitudinal axis which angle is in the range 1-20° and preferably in the range 7-10°. In Figure 8A the negative axial rake angle is provided by the cutting element having front and rear surfaces inclined with respect to one another whereas in Figure 8B the front and rear surfaces of the cutting element are parallel and the element as a whole axially inclined. The provision of such a negative axial rake angle provides an improved cutting effect. A further improvement to the cutting effect is afforded by inclining the radially outer edge of the element 20 downwardly with respect to radius 100 to provide the forementioned lead attack angle LA. It is believed that removal of swarf cuttings will be assisted if they are able to move more readily under centrifugal force to the radial outer edge of the blade and so the cutting

elements may be provided with a negative radial rake angle RR as shown in Figure 8C which is an angle made by each cutting element having a radial outer edge disposed angularly rearwardly of radius 100 with respect to a radially inner edge of the element 20. Such negative radial rake angle may be in the range 1-10° and preferably about 5°. In the Figures 8B and 8C the cutting edges have not been shown for clarity.

Referring to Figure 3, each of the cutting elements 20 has a leading cutting face 41 which incorporates the cutting edges 30 and recessed portions 31 and a rear face 42 which abuts the blade, the front and rear surfaces being inclined with respect to one another to provide the front surface 41 with the negative axial rake angle RA. In the embodiment of Figure 3 the elements 20 are located within slots formed in the leading face 17 of the blade and the slots are of constant depth in both longitudinal and radial directions, the negative axial rake angle being provided by the front and rear surfaces 41, 42 respectively of the cutting element 20 being inclined to one another.

One such cutting element 20 is shown in Figures 4A-4C, each cutting element 20 having a square cross-section with a length L and height H of 0.375 inches (9.5mm) and a depth D of 4.8mm, the distance h between each of the cutting edges 30 being 0.094 inches (2.3mm). As shown in Figure 7, each of the cutting edges 30 has an axial rake angle r_e in the range 0-40°, preferably 5-12°, what is known as land angle is in the range 0-35° preferably 3-15°. The cutting edge 30 protrudes from the recessed portion by distance d in the range 0.001-0.060 inches (0.025-1.5mm), preferably 0.003-0.015 inches (0.076-0.38mm). Thus the recess 31 has a negative rake angle portion 32 and a further, planar, portion 33 extending toward an adjacent cutting edge 30.

Although the length and height of the elements 20 of the preferred embodiment are the same it is to be understood that this is not necessary for the utility of the invention. The cutting elements are each made of tungsten carbide having European I.S.O. standard P10 to P60 hardness grade and with a cobalt content in the range 7%-20%, such as HSS grade tungsten carbide of Cutting & Wear Resistant Developments Ltd., Rotherham, England.

In use of the tool, when it is lowered into a drill hole on a drill string, the blades 5 are recessed into their respective slots 4. When the tool reaches the position where cutting is required to commence so fluid is pumped down the drill string to which the tool 1 is attached so as to activate piston 9 and cam 8 to move the blades 5 pivotally radially outwardly against the bias of spring 10 to a cutting position. The tool 1 is then rotated for cutting by the leading surface 41 of the cutting elements to

commence. The depth d and distance h of the cutting edges 30 in combination with the shape of the recessed portion 31 is arranged to provide a generally c-shaped swarf cutting having a thickness of 0.15 inches to 0.020 inches (0.38mm to .05mm).

The invention has so far been described in relation to one embodiment but other embodiments of the invention are envisaged will be described which are not intended to be limitative, and other embodiments of the invention will be self-evident to those skilled in the art. The blade shown in Figure 5A has cutting elements 20 disposed radially and axially adjacent to one another so that the portions of blade 24 between each cutting element are no longer present. The cutting elements 20 used are similar to those shown in Figures 4A-4C so that the blades 5 have parallel leading and trailing faces and the negative axial rake angle RA is provided by the inclined front and rear faces 41, 42 respectively of the elements 20. The blade shown in Figure 5B has cutting elements 120 with parallel front and rear surfaces 143, 144 respectively so that the leading surface 17 of the blade 5 has a staircase formation on the surface thereof to provide the negative axial rake angle RA. In Figure 5C the cutting element 120 is again used but the negative axial rake angle RA is provided by inclining the blade 5 relative to the axis 97. An embodiment of the cutting elements 120 is shown in Figures 6A-6C.

Although the cutter of this invention has been described in connection with a tool having pivotal blades it is to be understood that the cutter may also be used with a tool having fixed blades.

Although four cutting edges are described in the exemplary embodiment more or fewer cutting edges could be provided in dependence upon individual requirements. Also, although the cutting elements in the preferred embodiment have a quadrilateral cross section in the direction facing rotation of the tool, other shapes could be used such as triangular or hexagonal.

The present invention has the advantages that if a cutting edge should become worn then a new cutting edge is immediately exposed and by providing the cutting elements on the leading face of the blade in a staggered (brickwork) fashion so a continuous cutting edge is provided in a radial direction of the blade. The cutter of this invention therefore provides sharp cutting edges which are continuously exposed to provide efficient milling, the swarf cuttings (chips) that are cut by the tool are of a consistently small size and shape which results in efficient hole cleaning and as a result the rate of penetration of the tool embodying the cutter is rendered more consistent.

Claims

1. A cutter (5) for a downhole milling or cutting tool which tool is rotatable about a longitudinal axis (97), said cutter (5) comprising a blade (100) having a cutting surface (17), said cutting surface being formed by a plurality of cutting elements (20), characterised by each cutting element having a plurality of protruding cutting edges (30) each being longitudinally axially spaced from one another and interspaced by a recessed portion (31), whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is broken off when meeting the next, uppermost cutting edge.

2. A cutter as claimed in claim 1 wherein the cutting surface (17) extends in a generally radial direction across the intended direction of rotation of the tool and the cutting edges (30) also extend generally radially.

3. A cutter as claimed in claim 1 or 2 wherein each cutting element (20) has a negative radial rake (RR) as herein defined.

4. A cutter as claimed in claim 3 wherein the negative radial rake (RR) is 5° , and the cutting edges (30) are planar therewith.

5. A cutter as claimed in any preceding claim wherein each cutting element (20) is located on the blade (100) at a lead attack angle (LA) (as herein defined) in the range $1-15^\circ$.

6. A cutter as claimed in claim 5 wherein the lead attack angle (LA) is 10° .

7. A cutter as claimed in any preceding claim wherein each cutting element (20) is a discrete part, each of which is secured to the cutting blade (100) by one of brazing or soldering or welding.

8. A cutter as claimed in any preceding claim wherein the cutting elements (20) of odd numbered rows extending longitudinally are in line and even numbered rows extending longitudinally are in line and the even numbered rows are offset in a radial direction by half the radial length of a cutting element from the odd numbered rows.

9. A cutter as claimed in any preceding claim wherein each cutting element (20) is arranged to produce a negative axial rake angle (RA) with respect to the plane of the longitudinal axis, which angle is in the range $1-20^\circ$.

10. A cutter as claimed in claim 9 wherein each cutting element (20) is arranged to produce a negative axial rake angle (RA) with respect to the plane of the longitudinal axis, which angle is in the range $7-10^\circ$.

11. A cutter as claimed in any preceding claim wherein each of the cutting elements (20) is secured over a planar leading surface (17) of the blade and each element has a front cutting face (41) which is inclined with respect to the rear

surface (42) thereof, said rear surface abutting the blade so that the front cutting surface is provided with said negative axial rake angle (RA).

12. A cutter as claimed in any of claims 1-10 wherein each cutting element (120) has parallel front (143) and rear (144) faces and the leading face (17) of the blade has a generally radial slot formed therein which is inclined in the longitudinal axial direction to present the front face of the cutting element with a negative axial rake angle (RA).

13. A cutter as claimed in any of claims 1-10 wherein each cutting element (120) has parallel front (143) and rear (144) faces and the leading face (17) of the blade is formed in the longitudinal direction thereof in a staircase formation (Fig. 5B) with the part thereof extending in the longitudinal direction being inclined whereby when the cutting elements are positioned on the parts thereof extending in the longitudinal direction, a leading surface (41) of the cutting element presents a negative axial rake angle (RA).

14. A cutter as claimed in any of claims 1-10 wherein each cutting element (120) has parallel front (143) and rear (144) faces, the rear face being secured to a leading side of said blade (5) and said blade being inclined with respect to the longitudinal axis to provide said negative axial rake angle (RA).

15. A cutter as claimed in any preceding claim wherein four cutting edges (30) are provided on each cutting element.

16. A cutter as claimed in any preceding claim wherein each of the cutting edges (30) has a rake angle (RA) in the range $0-40^\circ$, and a land angle in the range $0-35^\circ$.

17. A cutter as claimed in any preceding claim wherein each of the cutting edges (30) has a rake angle (RA) in the range $3-12^\circ$ and a land angle in the range $3-15^\circ$.

18. A cutter as claimed in any preceding claim wherein the cutting elements (20) are each quadrilateral in cross-section.

19. A cutter as claimed in any preceding claim wherein the cutting elements (20) extend both in a radial and a longitudinal direction over the blade leading face (17).

20. A cutter as claimed in any preceding claim where the cutting edge (30) protrudes from the recessed portion (31) in the range 0.001-0.060 inches (0.025-1.5mm).

21. A cutter as claimed in any preceding claim wherein the cutting edge (30) protrudes from the recessed portion (31) in the range 0.003-0.015 inches (0.076-0.38mm).

22. A cutter as claimed in any preceding claim wherein each cutting element (20) is made from tungsten carbide having European ISO standard P10 to P60 hardness grade and with a cobalt

content in the range 7%-20%.

23. A cutter as claimed in any preceding claim wherein each blade (100) is located about the circumference of a tool body member (1) and each blade is pivotally (7) located to said body member.

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24. A milling or cutting tool for use in energy exploration, said tool being connectable to a drilling string and rotatable about a longitudinal axis (97), said tool having a cutter comprising a blade (100) having a cutting surface (17), said cutting surface being formed by a plurality of cutting elements (20), characterised by each cutting element having a plurality of protruding cutting edges (30) each being longitudinally axially spaced from one another and interspaced by a recessed portion (31), whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is broken off when meeting the next, uppermost cutting edge.

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25. A rotatable milling or cutting tool for use downhole including a body (1) having a longitudinal axis (97), a plurality of pivotally mounted blades (100) circumferentially spaced around the body, slot means (4) for receiving each blade in a contracted condition of said blade and means (7-10) for radially extending each blade, each blade having a cutting surface (17) formed by a plurality of cutting elements (20), characterised by each cutting element (20) having a plurality of protruding cutting edges (30) each being longitudinally axially spaced from one another and interspaced by a recessed portion (31), whereby in use swarf moves upwardly from one of the cutting edges along said recessed portion and is broken off when meeting the next, uppermost, cutting edge.

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26. A rotatable milling tool as claimed in claim 25 wherein the cutting surface (17) extends in a generally radial direction across the intended direction of rotation of the tool and the cutting edges (30) also extend generally radially.

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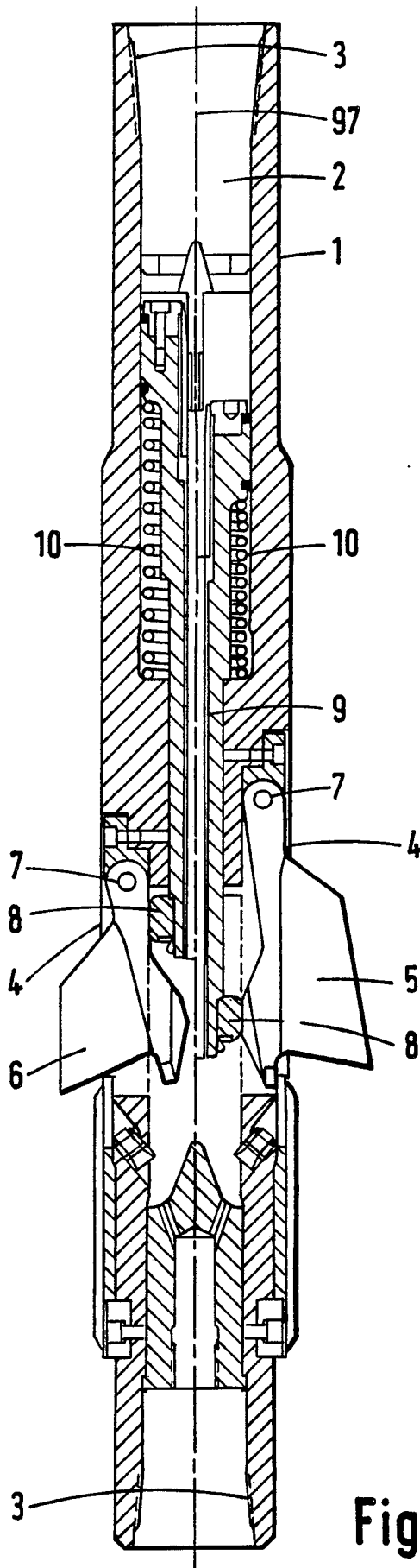


Fig. 1

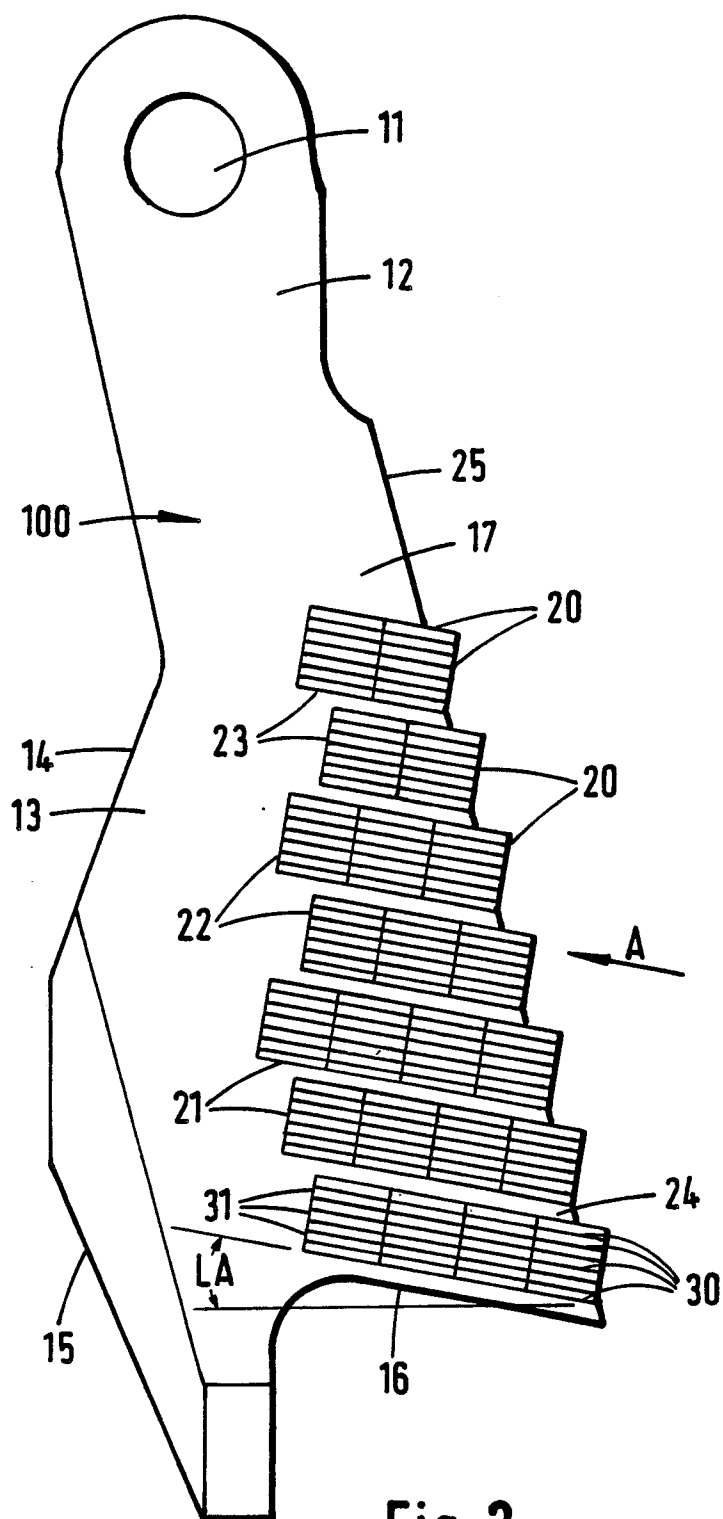


Fig.2

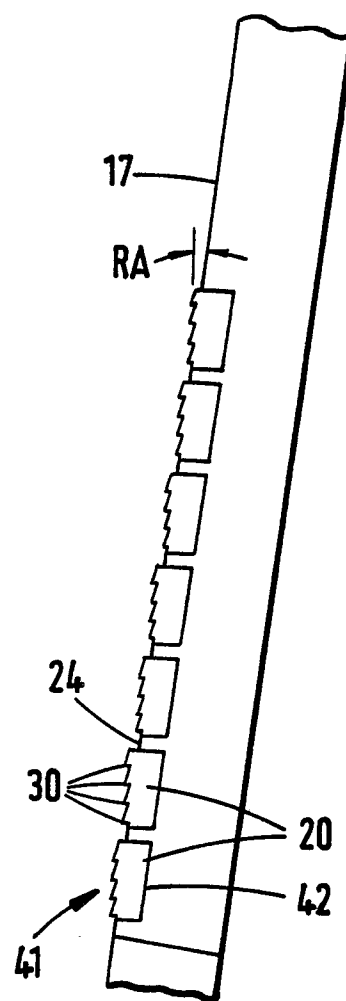


Fig.3

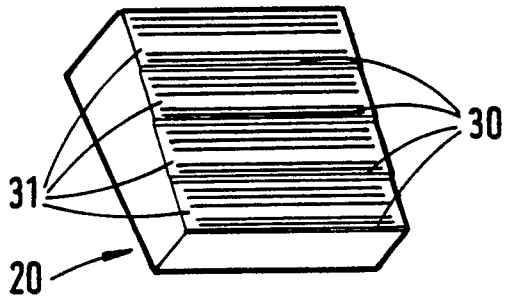


Fig. 4A

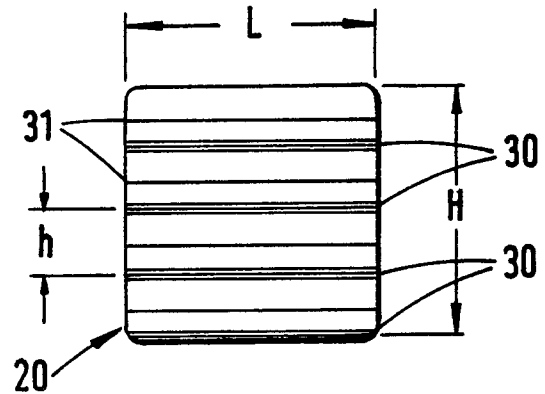


Fig. 4B

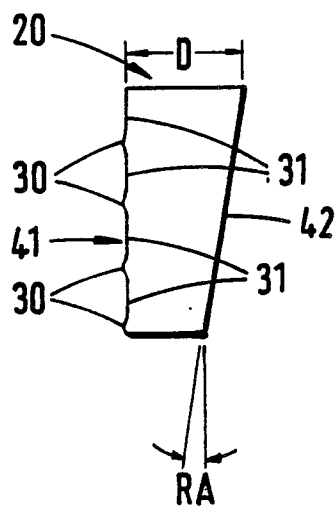


Fig. 4C

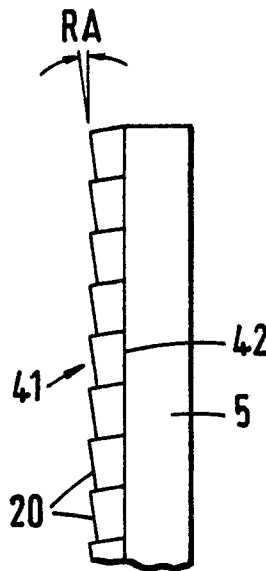


Fig. 5A

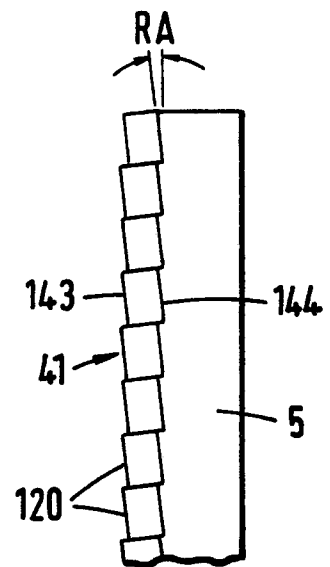


Fig. 5B

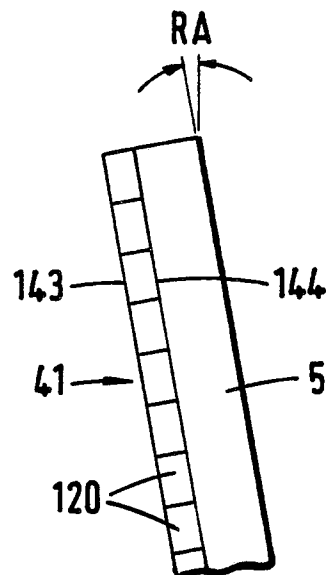


Fig. 5C

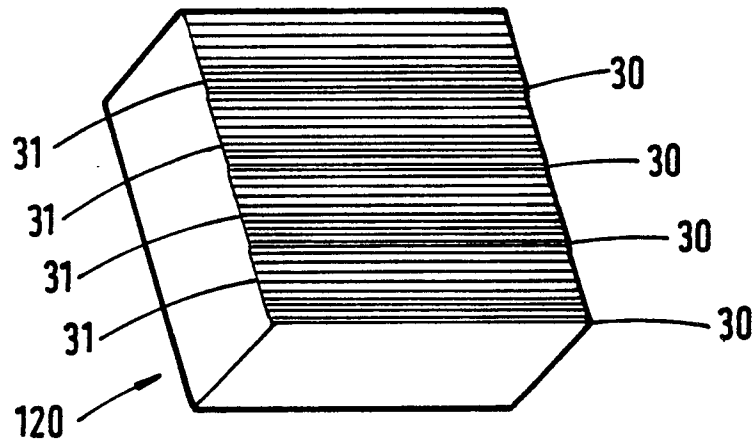


Fig. 6A

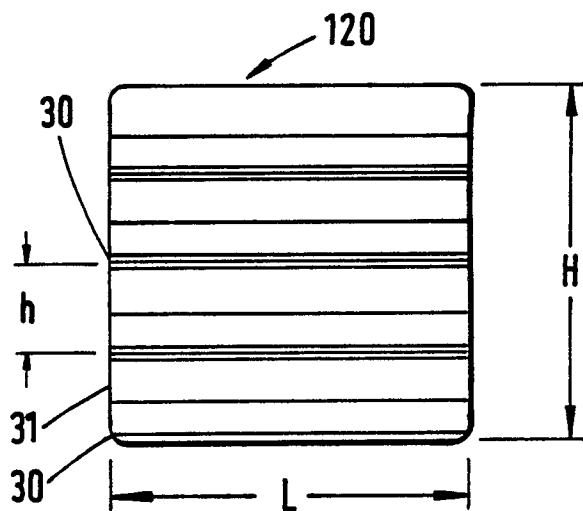


Fig. 6B

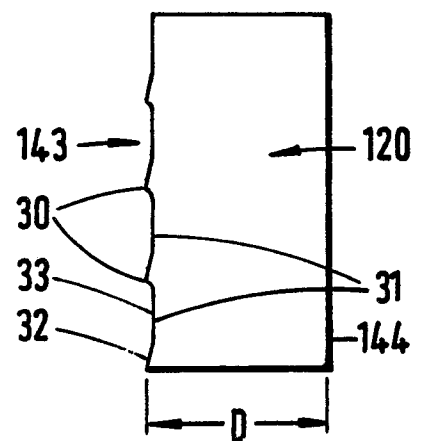


Fig. 6C

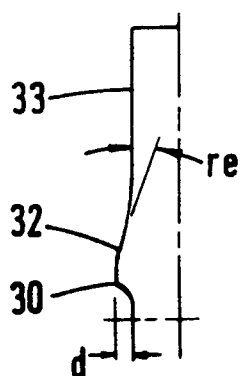


Fig. 7

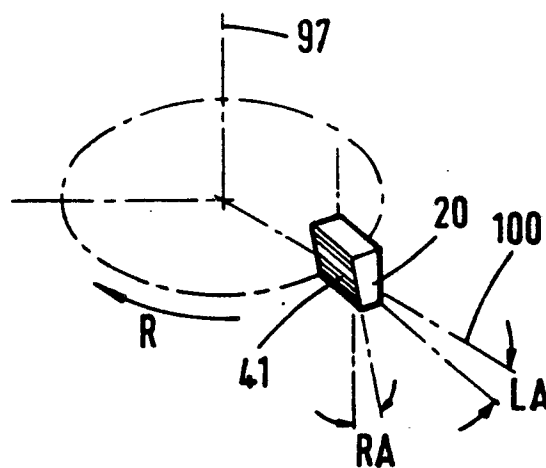


Fig. 8A

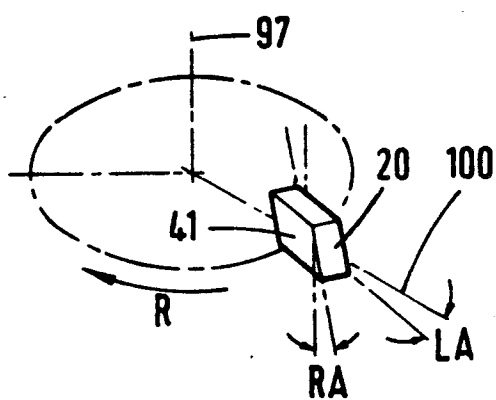


Fig. 8B

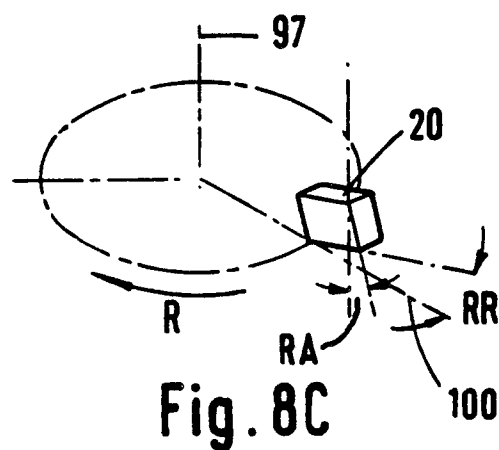


Fig. 8C



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-4 710 074 (SMITH INTERNATIONAL) * Column 4, line 35 - column 5, line 46; figures 4-6 *	1,2,5-7 ,9,10, 12,13, 18,24, 25	E 21 B 29/00 E 21 B 10/46
A	--- US-A-3 145 790 (BRIDWELL et al.) * Figures 4-6 *	1,24,25	
A	--- GB-A- 947 440 (JERSEY) * Figures 6-8 *	1,24,25	
A	--- US-A-4 717 290 (REYNOLDS) * Figures 2-9 *	1-7,9, 10,14, 24,25	
A	--- US-A-3 419 077 (SANFORD) * Figures 1,4 *	23,25, 26	
A	--- GB-A- 660 440 (HOOLE) -----		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.5) E 21 B B 23 B
Place of search THE HAGUE		Date of completion of the search 31-05-1990	Examiner RAMELMANN J.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			